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PICTORIAL REVIEW

Pancreaticoduodenectomy: expected post-operative anatomy and complications

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ABSTRACT

Pancreaticoduodenectomy is a complex, high-risk surgical procedure performed for tumours of the pancreatic head and other periampullary structures. The rate of perioperative mortality has decreased in the past number of years but perioperative morbidity remains high. This pictorial review illustrates expected findings in early and late post-operative periods, including mimickers of pathology. It aims to familiarize radiologists with the imaging appearances of common and unusual post-operative complications. These are classified into early non-vascular complications such as delayed gastric emptying, post-operative collections, pancreatic fistulae and bilomas; late non-vascular complications, for example, biliary strictures and hepatic abscesses; and vascular complications including haemorrhage and ischaemia. Options for minimally invasive image-guided management of vascular and non-vascular complications are discussed. Familiarity with normal anatomic findings is essential in order to distinguish expected post-operative change from surgical complications or recurrent disease. This review summarizes the normal and abnormal radiological findings following pancreaticoduodenectomy.

Pancreaticoduodenectomy was first performed in 1909 and was popularized by the American surgeon Allen Whipple, who refined the technique in the 1930s. Indications for the procedure include pancreatic head tumours, periampullary tumours, distal common bile duct tumours and chronic pancreatitis involving the pancreatic head. The mortality rate of the procedure has decreased from >20% to <2% in high volume centres, making it a more attractive option now than it previously was.¹ However, perioperative morbidity rates remain high (30–40%). Many patients require post-operative imaging and radiologic intervention. Timely recognition of complications is important.

EXPECTED POST-OPERATIVE FINDINGS AND MIMICKERS OF PATHOLOGY

Understanding the surgical procedure and the expected post-operative findings is essential when interpreting imaging. The components of a standard pancreaticoduodenectomy are distal gastrectomy, duodenectomy, partial pancreatectomy, partial choledochectomy, cholecystectomy and proximal jejunectomy. A jejunal loop is mobilized up to the right upper quadrant and three anastomoses are formed: gastrojejunostomy, hepaticojejunostomy and pancreaticojejunostomy (Figure 1). Distal gastrectomy facilitates resection of nodes

along the greater and lesser curves of the stomach, reduces delayed gastric emptying and theoretically reduces the risk of gastritis post-operatively.

Pylorus-preserving pancreaticoduodenectomy, first described in 1944,² has gained popularity in the past two decades. It involves preservation of the stomach and proximal duodenum and formation of a duodenojejunostomy (Figure 1). There is debate in the literature regarding the advantage of pylorus-preserving pancreaticoduodenectomy compared with standard pancreaticoduodenectomy. Preservation of the distal stomach results in reduced frequency of dumping syndrome and bile reflux. Other potential benefits include faster operation time and reduced blood loss.³ There is no difference in morbidity, hospital mortality or survival between the procedures. Patients who undergo pylorus-preserving pancreaticoduodenectomy have a higher incidence of delayed gastric emptying compared with standard pancreaticoduodenectomy. There is currently insufficient evidence to favour one procedure over the other. The majority of surgeons at St Vincent's University Hospital (Dublin, Ireland) perform standard pancreaticoduodenectomy and all of the examples included in this review are of the standard procedure.

Figure 1. Diagrams of anatomy post pancreaticoduodenectomy (a) and post pylorus-preserving pancreaticoduodenectomy (b) with surgical anastomoses depicted. Intraoperative photographs from a standard pancreaticoduodenectomy delineate the three anastomoses: gastrojejunostomy (c), hepaticojejunostomy (d) and pancreaticojejunostomy (e).

A number of expected catheters and drains may be seen on early post-operative imaging. Surgical drains are typically located adjacent to anastomoses. Intraoperative pancreatic stent placement potentially reduces the incidence of pancreatic fistula formation. Jejunostomy feeding catheters allow enteric feeding distal to anastomoses.

Normal post-operative findings can mimic pathology on CT. Pneumobilia occurs because of the presence of a patent hepaticojejunostomy. The jejunal loop can potentially be mistaken

for a fluid collection in the right upper quadrant. Oedema of the mobilized jejunal loop is a common finding and may be mistaken for ischaemia (Figure 2). Reactive lymphadenopathy is common.

EARLY NON-VASCULAR COMPLICATIONS

Delayed gastric emptying occurs in approximately 20% of patients.⁴ It is defined as persistent requirement of a nasogastric catheter more than 10 days post surgery. CT is frequently performed in this clinical setting to assess for drainable fluid collections that may alleviate symptoms (Figure 3).

Figure 2. Acute deterioration Day 3 post surgery for pancreatic adenocarcinoma. CT shows an oedematous jejunal loop (arrow). This was mistaken for hypoenhancement and was reported as suspicious for ischaemia. Explorative laparotomy showed normally perfused bowel. Note the expected findings of a pancreatic stent (arrowhead) and a surgical drain (short arrow).

Figure 3. Persistent vomiting Day 11 post surgery for pancreatic adenocarcinoma. Coronal CT shows distension of the residual stomach. Note the normal post-operative findings of pneumobilia (arrow) and oedematous jejunal loop.

Post-operative collections happen in at least 10% of patients, typically occurring in the retroperitoneal surgical bed.⁵ Owing to the considerable intraperitoneal component of the procedure, they may also occur within the peritoneal cavity. Intraperitoneal fluid migrates easily, and pelvic collections remote from the surgical site are a common finding. Fluid is frequently seen in the surgical bed early post operatively. This is not necessarily infected and does not mandate drainage. If there is clinical suspicion of infection (pyrexia, leucocytosis and abdominal pain) or if the collection demonstrates rim enhancement or contains gas, the patient may benefit from percutaneous drainage. Drainage may be performed with ultrasound or CT guidance using a Seldinger technique or direct catheter placement (Figure 4).⁶ Catheter displacement post drainage is not uncommon. Education of the patient and nursing staff regarding catheter care is important to prevent this.

Pancreatic fistula is defined as drain output of amylase-rich fluid (amylase content greater than three times serum amylase). It can be diagnosed radiologically by demonstrating communication between the drainage catheter and the pancreatic duct (Figure 5). It occurs in up to 20% of patients.⁴ It can lead to sepsis

Figure 4. Fever, pain and leucocytosis Day 14 post surgery for pancreatic neuroendocrine tumour. Axial CT image shows a fluid collection (arrow) in the resection bed (a). A drainage catheter was placed using CT guidance and frank pus was drained. Coronal reformat from follow-up CT (b) shows satisfactory catheter position (arrow) with reduction in size of the collection.

or haemorrhage owing to the erosive capacity of pancreatic enzymes. Biloma is clinically diagnosed by the presence of bile in the drain fluid. It can be diagnosed radiologically by demonstrating a communication between the drainage catheter and the biliary tree (Figure 5). It occurs in <2% of patients.⁴

LATE NON-VASCULAR COMPLICATIONS

Hepatic abscesses can be an early or late complication of surgery. They may occur because of reflux of enteric contents through the hepaticojejunostomy into the liver or as a result of ischaemic cholangiopathy (Figure 6). Options for abscess drainage are as outlined above.⁶

Biliary strictures are typically a late complication and may result from anastomotic stricturing, bile duct injury or recurrent tumour. MR cholangiopancreatography is frequently utilized to demonstrate the level of obstruction. Supportive features of malignant obstruction on imaging include evidence of local recurrence or metastases (Figure 7). Because bowel anatomy is surgically altered, it is frequently difficult to endoscopically access the biliary system; a percutaneous approach is commonly required. Brushings and washings should be obtained during percutaneous biliary drainage for histological and cytological analysis. Benign biliary strictures have been shown to respond well to percutaneous balloon dilatation (Figure 8).⁷ Malignant biliary strictures can be treated with palliative metal stenting. Rarely, biliary obstruction can result in bile leak and biloma formation.

VASCULAR COMPLICATIONS

Post-operative haemorrhage occurs in <10% of patients but accounts for up to 38% of mortality.⁸ Radiologists must be keenly aware of this and act immediately when patients develop signs of haemorrhage. CT angiography can demonstrate the cause, site and nature of bleeding. Haemorrhage typically occurs from the gastroduodenal artery; it is the first place to look for complications (Figure 9). This artery is cut and ligated intraoperatively at its origin from the common hepatic artery. Hepatic artery erosions are increasingly recognized, occurring as a result of pancreatic leaks. Endovascular intervention is preferred to surgery because of lower mortality. Options include embolization or exclusion with a covered stent. Vascular complications can also occur secondary to post-operative interventions (Figure 10).

Post-operative ischaemia is an underestimated cause of death post pancreaticoduodenectomy (Figure 11). It can occur owing to pre-existing stenoses of coeliac or superior mesenteric arteries or owing to intraoperative hepatic artery injury. In one large cohort, ischaemia represented 36% of overall mortality.⁹ Pre-operative management of stenoses and meticulous dissection of the hepatic artery can minimize ischaemic complications.

RARE COMPLICATIONS

Several unusual complications of pancreaticoduodenectomy have occurred in our institution and are included for the reader's interest. Pancreatic duct stenting is performed in an attempt to reduce the incidence of fistula formation but results of its efficacy are discordant. The stents are associated with their own intrinsic set of complications, including obstruction, migration, pancreatitis

Figure 5. Two cases of complicated post-operative leaks; one of a pancreatic fistula and one of a biloma. Case 1: coronal CT reformat (a) shows a drainage catheter in a collection (arrow) inferior to the pancreaticojejunostomy. Tubogram through the drainage catheter (b) shows communication with the main pancreatic duct (arrow). Catheter fluid amylase was markedly elevated at 10,874 U/l consistent with a pancreatic fistula. Case 2: axial CT image shows a fluid collection (arrow) in the gallbladder fossa (c). Note the expected finding of a pancreatic stent (arrowhead). Percutaneous drainage of the collection was performed. Contrast injection through a percutaneous catheter tract via a sheath (d) shows communication to the central right hepatic duct (arrow). Contrast drains from this through the hepaticojejunostomy. Catheter fluid bilirubin was elevated at 10 mg dl⁻¹.

and dilatation of the remnant pancreatic duct (Figure 12). Rare case reports describe stent migration into the appendix and as the cause of a bezoar ileus. Combined percutaneous and endoscopic removal of migrated stents has been documented in the literature.¹⁰

CONCLUSION

Familiarity with normal anatomic findings is essential to distinguish expected post-operative change from surgical complications or recurrent disease. This review summarizes the normal and a variety of abnormal radiological findings following pancreaticoduodenectomy.

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Figure 6. Short history of anorexia, abdominal pain and rigors 9 years post surgery for duodenal adenocarcinoma. Axial CT image shows a bilobed thick walled fluid collection (arrow) in segments VIII and IVa of the liver. Ultrasound-guided drainage was performed, and frank pus was drained. Catheter fluid culture was positive for *Escherichia coli*.

Figure 7. Cholangitis 6 months post surgery for pancreatic adenocarcinoma. Axial CT image (a) demonstrates dilatation of the afferent loop of the hepaticojejunostomy (aff), decompression of the efferent loop (arrow) and a soft-tissue mass at the hilum (asterisk). Image from percutaneous transhepatic cholangiogram (b) shows a similar appearance of biliary dilatation and distension of the afferent jejunal loop (arrow). The hepaticojejunostomy is patent and a catheter has been passed into the afferent loop. Despite multiple attempts, it was not possible to cannulate the efferent loop. A presumptive diagnosis of tumour recurrence in the efferent loop was made; the patient subsequently developed hepatic metastases. Palliative placement of an external biliary drain was performed.

(a)

(b)

Figure 8. Recurrent cholangitis 3 years post surgery for pancreatic adenocarcinoma. Coronal MR cholangiopancreatography image (a) shows a stricture (arrow) of the common hepatic duct with associated intrahepatic duct dilatation. Image from percutaneous transhepatic cholangiogram (b) demonstrates balloon dilatation with waisting of the balloon (arrow) at the site of maximum stenosis. Post-dilatation cholangiogram demonstrated no residual stricture. The patient has not developed recurrent symptoms since the procedure.

(a)

(b)

Figure 9. Hypotension and bleeding from surgical drain Day 20 post surgery for pancreatic adenocarcinoma. Axial image from arterial phase of CT angiogram shows active extravasation of contrast from a pseudoaneurysm at the site of the gastroduodenal artery stump (arrow). There is surrounding haematoma. Successful proximal coil embolization of the common hepatic artery was performed.

Figure 10. A rim enhancing fluid collection lateral to the superior mesenteric vein was drained under CT guidance Day 8 post surgery for distal common bile duct cholangiocarcinoma. The catheter was accidentally displaced later on the ward and was manipulated back into the retroperitoneal collection using fluoroscopic guidance. Satisfactory repositioning is confirmed at follow-up CT. Subsequently, the catheter drained blood. A tubogram was performed that shows frank communication with the portal system (arrow), presumed to be related to injury at the time of catheter displacement. The catheter was clamped with intention for it to remain *in situ* indefinitely. It fell out at home 3 months later with no clinical sequelae.

Figure 11. Critically unwell Day 19 post surgery for ampullary adenocarcinoma. Reformatted axial image (a) from a triphasic CT shows occlusion of the hepatic artery (arrow) and extensive portal venous gas. Coronal image (b) shows occlusion of the main portal vein (arrow) and parenchymal gas in Segment VI. The patient died shortly afterwards despite maximum ventilator and inotropic support.

(a)

(b)

Figure 12. Two cases of stent migration. Case 1: axial CT image (a) shows a pancreatic stent (arrowheads) that has migrated through the pancreaticojejunostomy into the liver parenchyma resulting in abscess formation (arrow). A drainage catheter was placed within the collection using ultrasound guidance and frank pus was aspirated. Tubogram (b) performed at the end of the procedure outlines the abscess cavity and the pancreatic stent (arrow). Percutaneous retrieval of the stent was attempted but was unsuccessful. The patient developed hepatic metastases after a short interval and the drainage catheter was kept *in situ* while the patient received palliative chemotherapy. The patient died with the migrated stent and drainage catheter *in situ*. Case 2: reformatted coronal CT image (c) shows a migrated stent (arrowhead) adjacent to a 9-mm pseudoaneurysm related to a replaced right hepatic artery (arrow). The pseudoaneurysm was presumed to have developed as a result of the stent migration and was subsequently identified at formal angiography where coil embolization was successfully performed.